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ABSTRACT

The auditory/verbal short-term memory of 64 college students was examined across a wide range of retention intervals (5 seconds to 60 seconds). High attention during interpolated processing was ensured by monitoring rehearsal with a combination of methods, and errors were analyzed for evidence of proactive and intra-unit interference. Recall of three- and five-digit items was excellent under the conditions of modality isolation of interpolated processing. In fact, only 4% of all three-digit items and 10% of all five-digit items were forgotten for reasons other than proactive intrusion of intra-unit interference. The results support an interdependent model of attention and modality effects in short-term forgetting. (Author/FL)

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ATTENTION AND MODALITY EFFECTS IN STM:

A SECOND LOOK

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Abstract

Auditory-verbal short-term memory was examined across a wide range of retention intervals (5 seconds to 60 seconds). High attention during interpolated processing was ensured by monitoring rehearsal with a combination of methods, and errors were analyzed for evidence of proactive and intra-unit interference. Recall of 3- and 5-digit items was excellent under the conditions of modality isolation of interpolated processing. In fact, only 4% of all 3-digit items and 10% of all 5-digit items were forgotten for reasons other than proactive intrusion or intra-unit interference. The results support an interdependent model of attention and modality effects in short-term forgetting.

Attention and Modality Effects in Short-Term Memory: A Second Look[1]

Thomas Evans and Joe Byers[2]

Recent short-term memory (STM) studies have attempted to determine the importance of attention demands and modality of presentation of the interpolated task in the STM distractor task paradigm. Attention demands are important, assuming that attention is necessary for maintaining information (i.e., to rehearse) and that forgetting occurs when the attention required for interpolated processing interferes with information maintenance (Deutsch, 1970; Kahneman, 1973; Yuille & Ternes, 1975). The attention demands of the interpolated task are viewed as a critical variable. A design problem here, noted by Yuille and Ternes, is that the attention demands of a task are frequently confounded by the type of interference which occurs during interpolated processing.

Modality effects are important, assuming ST forgetting is due to cognitive processing of information similar to the memory items (Bird, 1976; Reitman, 1971; Shiffrin, 1973; Underwood, 1966). Hence a shift to a different modality for the retention interval should minimize interference and memory loss (Bower, 1970; Deutsch, 1970; Elliott, 1973). To date, however, results of STM studies have been ambiguous and often contradictory. Investigators have failed to prevent bimodality storage

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[1]The authors wish to thank Mark J. Thuston for pilot work and aid in material production and design.

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of either the memory items or the interpolated items, or both (Elliott, 1973; Murray & Newman, 1973; Watkins, Watkins, Craik, & Mazuryk, 1973). Evidence for separate visual and auditory stores was presented throughout Penney's (1974) review of modality effects, but it was continually confounded by the contrast of visual and auditory presentation of verbal *items*. Verbal items may be sub-vocally articulated (i.e., have auditory-articulatory components) regardless of presentation modality (Peterson & Johnson, 1971). With the tendency of most verbal materials to have some degree of visual-imaginal associations (Paivio, 1971) the visual-verbal/auditory-verbal dichotomy becomes doubly confounding.

In a comparison study of attention and modality effects in STM, Yuille and Ternes (1975) focused on the retention of visual vs. verbal memory items, varying both the attention demands and the modality of the interpolated task (high vs. low attention demand and verbal vs. visual modality). They concluded that their results supported an additive model of independent attention and modality effects.

We agree that both attention and modality effects are important but we do not agree that an additive model was clearly supported; the researchers did not clearly separate modalities, and they failed to measure attention. Their use of concrete nouns as verbal items maximized the probability of imaginal coding (Paivio, 1971), and it can be argued that the high-attention visual condition elicited verbal mediation.

Yuille and Ternes contend that the visual pattern was not verbally codable; that is probably true, but the likelihood that the newly-learned motor responses were guided by implicit verbalizations such as "Up," "Down," cannot be ruled out (Klausmeier, 1975; Miller, Galanter & Pribram,

1960). More importantly, the authors made no attempt to minimize or measure rehearsal, or to measure proactive interference (PI) effects, attributing their results, instead, to variations in attention demands. Without PI and rehearsal measures, the contribution of attention demands cannot be derived from the data.

Although Reitman (1974) has found that surreptitious rehearsal cannot be completely eliminated, it does not follow that researchers should abandon efforts to control rehearsal. Numerous studies, in fact, have indicated the effectiveness of various techniques for measuring or controlling rehearsal; these include instructing subjects not to rehearse, directing subjects to report rehearsal (Keppel & Underwood, 1962; Kroll, Kellicut, & Parks, 1975), monitoring interpolated task errors, and use of delayed reaction times (Butterfield, Peltzman, & Belmont, 1971; Reitman, 1974). Unless the explicit purpose of a study is to measure or manipulate rehearsal, every technique available should be used to minimize effects of rehearsal. A clearer picture of the importance of modality and attention effects in ST forgetting would be provided by a Yuille and Ternes-type study with (1) more complete modality isolation, (2) monitoring of rehearsal, and (3) measurement of interference effects. In our study we assumed, contrary to Yuille and Ternes, that attention and modality effects in STM are interdependent -- that they are multiplicative rather than additive. Hence, we predicted that a distractor task with maximum attention demands (as indicated by no rehearsal) would not interfere with retention of the memory item if the distractor task involved processing in an isolated modality. We attempted to replicate the portion of the Yuille and Ternes study dealing with auditory/verbal memory items and a visual/nonverbal interpolated task.

We examined auditory-verbal memory in a Brown-Peterson paradigm with interpolated task items similar to Meudell's (1977) memory items (visual patterns). In a series of experiments, we tried to resolve the methodological problems discussed above by (1) designing a high-demand visual interpolated task which was truly isolated from the auditory-verbal modality of the memory items and (2) ensuring high-attention during the interpolated task by using every possible index of rehearsal as an indication of attention breakdown.

To satisfy the first provision, we used auditorily-presented items of low-imagery value, consisting of either 3 or 5 digits, and a purely visual (Meudell, 1977), nonverbally-codable (Evans, 1972; Evans & Denny, 1976) high-demand pattern-matching task (Schnore & Partington, 1967). We controlled rehearsal by instructing subjects to stop pattern-matching and to report rehearsal the instant it occurred; we questioned subjects after each trial and discarded any trial for which we found an indication of rehearsal or possible rehearsal. Discards included all trials involving logistic problems, pauses, or interpolated task errors. We assumed (as did Meudell, 1977) that by isolating the memory item from the processing of the interpolated item we would eliminate any retroactive interference effects. Thus, we believed that any memory loss as a function of retention interval would be attributable to measureable interference effects, or to memory-trace decay.

To measure interference effects directly, we conducted an analysis of errors in which both PI and intraunit interference (II) were defined in a precise operational way. Since PI effects across trials are

probably masked by practice effects (Keppel & Underwood, 1962; Meudell, 1977), we reasoned that an analysis of only preceding item intrusions (Bennett & Kurzeja, 1976; Dillon & Thomas, 1975) would be a more sensitive indicator of multitrial PI than would the traditional method of simply plotting performance as a function of the number of trials. Under these conditions, we felt it would be possible to assess optimal STM performance with a high-attention interpolated task.

Experiment I

Method

Subjects. The subjects were 64 undergraduate volunteers.

Apparatus. Memory items were 24 random 5- and 3-digit permutations (the first three digits of the 5-digit permutations were used as the 3-digit items). Interpolated task materials included 12 computer-generated, visual patterns; patterns consisted of eight randomly blackened squares on a 5 x 5 (7.5 cm x 7.5 cm) matrix. Any patterns rated positively for verbal encodability (Evans, 1972) were eliminated. The others were printed on 10 cm x 12.5 cm cards for presentation in an Electrotach 40010 manually-operated tachistoscope (t-scope). These patterns were to be matched with one of three smaller patterns (4 cm x 4 cm), which were randomly ordered and printed on a 10 cm x 12.5 cm card, one card corresponding to each of the larger patterns. The timer was a GraLab Universal model 172.

Procedure. Subjects participated individually in single sessions lasting 15-30 minutes each. There were eight memory conditions,

crossing 2, 4, 8, or 12-pattern matches with 3- or 5-digit memory items. A between-subjects design was employed; each subject received 12 trials per condition and eight subjects were assigned to each condition. Trials were discarded, and not replaced, if any of the following problems occurred: logistic difficulties on the part of either the experimenter or the subject, subject-reported rehearsal, pattern-matching errors, relative delays or pauses in pattern-matching, or external interference. Recall was recorded as the percent of memory items completely recalled from completed trials. All subjects were given two practice trials of six patterns each; the patterns consisted of experimenter-generated memory items.

Instructions: At the beginning of the session, the experimenter told the subject:

> "I am going to read you a 3(5)-digit number. As soon as you hear the last digit, flip this switch on (to the t-scope) and look at the pattern visible inside. Match it to one of the three patterns on the top card in front of you, indicating your choice by touching the appropriate pattern. Turn that card over to one side, look up for the next pattern, and match it to one of the three patterns on the next card. Continue matching in this way until you have matched all the cards in the pile, then try to remember the 3(5)-digit number. (All subjects assumed that a vocal response was desired.) You are not to try to remember the number at any point before you finish matching the pile. Do not repeat it to yourself when I say it, but begin immediately matching patterns. If the number does pop into

your head, or you find yourself running through it, or saying it to yourself, stop and tell me that you rehearsed and we will go on to the next trial. The important thing is to match the patterns accurately and eventually to work up some speed at it. If you touch the wrong one by mistake, change your choice immediately, but do not say anything. Any comments may disrupt your performance. When you finish the pile, say only the first 3(5) digits that come to mind, even if you think you have drawn a blank, because chances are good they will be right anyway."

The experimenter read the memory items at the rate of two digits per second, and recorded the number of seconds the subject spent on the interpolated task for each trial. The subjects were questioned about rehearsal at the end of each trial, and if they had difficulty controlling rehearsal, they were advised to match the patterns faster. Subjects had to make the match from memory to prevent rehearsal; thus the pattern was changed as soon as the subject looked at it.[3]

Results and Discussion

Recall for 3-digit items was 99, 97, 97, and 94% for 2, 4, 8, and 12 interpolated patterns, respectively. The percent recall for 5-digit items was 76, 68, 70, and 57, respectively (see Figure 1). A 2 x 4 independent analysis of variance (ANOVA) was computed, with memory-

[3]Rehearsal of the memory item during interpolated task performance is an indication that the subject is not completely attending to the interpolated task. If interpolated task performance (i.e., rate and accuracy) is disrupted by rehearsal, it is reasonable to assume that the attention demands of the interpolated task are not sufficient. Extensive pilot work was done with slide presentation and response keys until a procedure and materials were developed which showed sufficient task difficulty to consistently prevent rehearsal.

item size (3 vs. 5) and number of interpolated patterns (2, 4, 8, or 12) as the main factors. Memory-item size was a highly significant factor $F(1, 31) = 65.175$, $p < .001$), while number of patterns and the pattern-by-item interaction were not ($F(3, 15) = 1.37$ and $F(3, 42) = 1.06$, respectively). These data indicate that the processing of interpolated items did not interfere with ST retention of auditory-verbal items, i.e., that there was no measurable retroactive interference (RI). The data do not suggest that attention diversion was a mechanism of forgetting in STM, since significant loss did not occur during the high-attention interpolated task.

Although 5-digit recall was less than 3-digit recall, the difference may have been attributable to PI and II effects, which logically should be greater for 5-digit than for 3-digit items (Melton, 1963). To determine the extent to which these interference effects accounted for the increased forgetting, we analyzed the nature of the forgetting errors. PI was operationally defined as the appearance of one or more digits from the previous item in the same serial position (95% of cases), or the appearance of two or more adjacent digits not in serial position. II was defined as correct identification of digits, but in the wrong serial position (30% of cases were reversals of two adjacent items). (It was possible to find more than one type of error in a single missed item.) All other errors were recorded as unaccounted for (u).

To check the PI measurement against random effects, we also scored all missed items for PI against the memory item <u>following</u> the missed item. We assumed that this control measurement would provide a baseline of spurious PI to compare with the true PI measurement.

The total number of errors for 5-digit items was 132, while the number of missed items was 101. II errors accounted for 55% of the

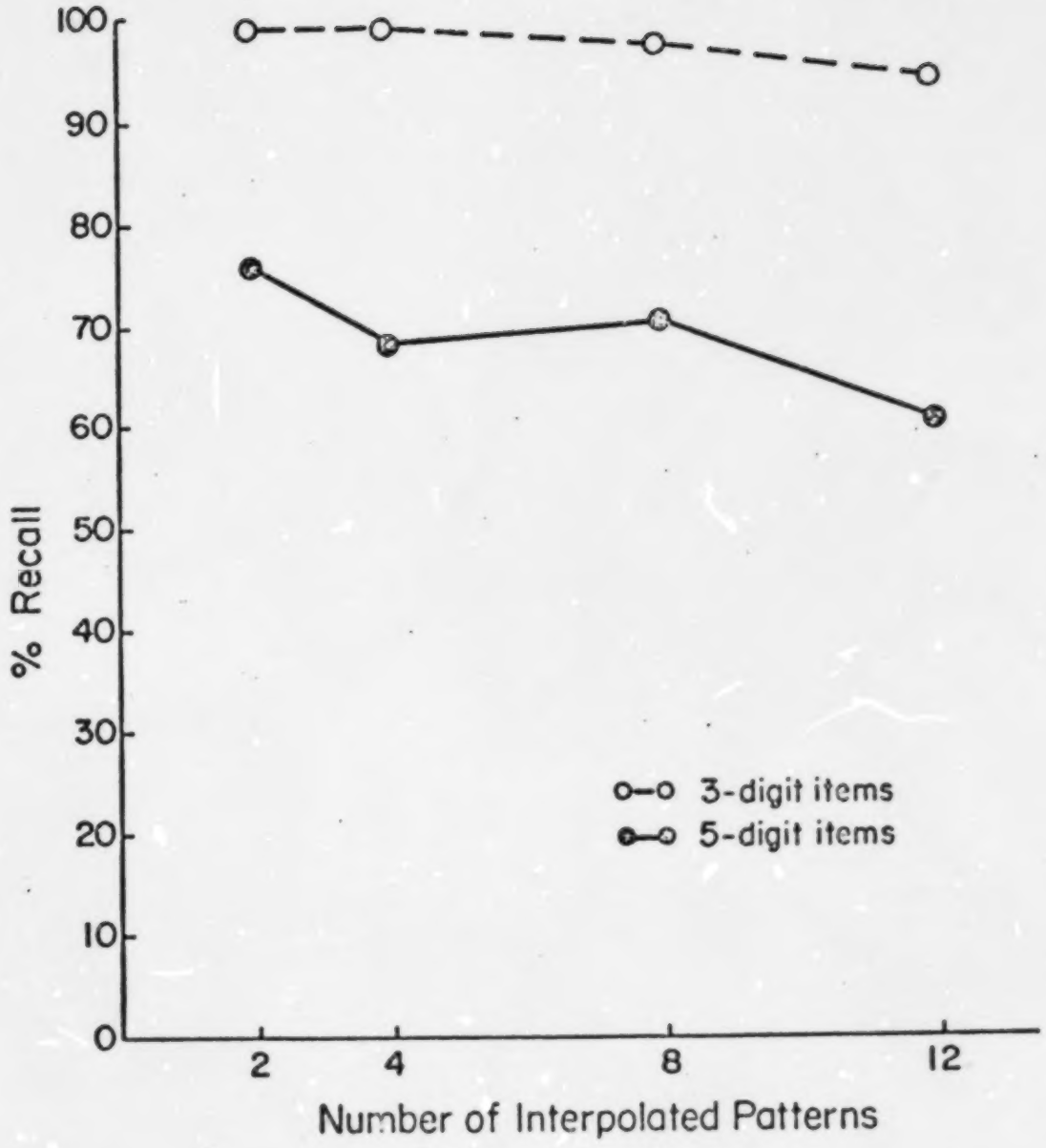

Figure 1. Percent recall as a function of number of interpolated patterns (Experiment 1).

errors, PI for 23% (control PI produced 4.5% errors). Of the total items missed, only 4% could not be attributed to either PI or II, or to both. (See Table 1 for a summary of errors.) There were very few errors with 3-digit items and only .6% of the forgotten items could not be explained by PI or II. Since the two interference measures employed were not exhaustive, these data indicate only that very little forgetting occurred due to either the passage of time or the processing of the interpolated visual material.

Experiment 1 demonstrated that the number of interpolated patterns did not affect retention, so in Experiments 2 and 3, we controlled the length of retention intervals while allowing the number of patterns per subject to vary. To allow for a comparison graph of the results of all three experiments, we plotted the retention data from Experiment 1 in terms of mean retention interval per subject (see Figure 2). The respective means (and corresponding intersubject ranges) for 2, 4, 8, and 12 patterns were 5.3 seconds (3.9-6.7), 8.6 seconds (6.4-10.3), 17.4 seconds (13.7-22.1), and 24.7 seconds (17.8-35).

Experiment 2 was designed to examine specifically the range of time associated with PI effects in earlier studies, 9 to 21 seconds.

Experiment 2

Method

Subjects. The subjects were 27 undergraduate volunteers.

Apparatus. Memory items were 47 random 5-digit permutations. Interpolated task materials were 24 new patterns designed as in Experiment 1. A total of 372 large pattern cards and 372 corresponding match cards were ordered by sequential permutations of the 24 pattern designs.

Table I: Auditory/Verbal STM

Analysis of Errors for 3- and 5-digit Memory Items in Experiments 1, 2, and 3

	Total items	Total items missed	Total errors	% PI errors	% II errors	Total items u[a]	% items u	%Items u with PI control
Ex. 1 3-digit	316	10	11	73%	0%	2	.6%	.6%
Ex. 1 5-digit	316	101	132	23%	55%	12	4%	4%
Ex. 2 5-digit	675	235	315	34%	43%	37	5%	9%
Ex. 3 5-digit	225	96	141	30%	43%	14	6%	10%
Ex. 3 3-digit	225	20	24	38%	25%	7	3%	4%

[a] u = unaccounted for, i.e., not attributable to either PI or II

Procedure. A within-subjects design was employed wherein each subject completed five trials under each of the five retention intervals of 9, 12, 15, 18, and 21 seconds; a sequence of intervals was randomly selected and held constant for all subjects for 25 trials.

The first two trials on the list of 47 were practice trials of 15 seconds each. Whenever a trial was discarded (for the same reasons as in Experiment 1), its number and the length of the retention interval were reentered in the remaining list of 20 make-up trials. One subject, who had not completed 25 trials (five at each interval) by the end of this make-up sequence, had extreme rehearsal difficulties and his data were discarded.

Instructions. The instructions were almost the same as before but restricted to 5-digit items. The subject was instructed to continue matching until the experimenter said the word "recall;" that was the signal for the subject to respond with the memory item. Subjects were not told that additional trials were being added to replace discarded trials.

Results

Experiment 2 produced a virtually flat recall curve from 9 to 21 seconds, with recall at 66, 66, 64, 65, and 64% (see Figure 2). A one-way repeated measure ANOVA showed no effects of retention interval, $F(4, 104) = .06$, n.s. The error analysis was conducted with the same definitions as in Experiment 1 and the results were similar. The total number of errors was 315, with 235 missed items, 34% PI errors, 43% II errors, and 16% u. Thus, only 5% of the 675 memory items were forgotten for reasons other than PI or II (see Table 1).

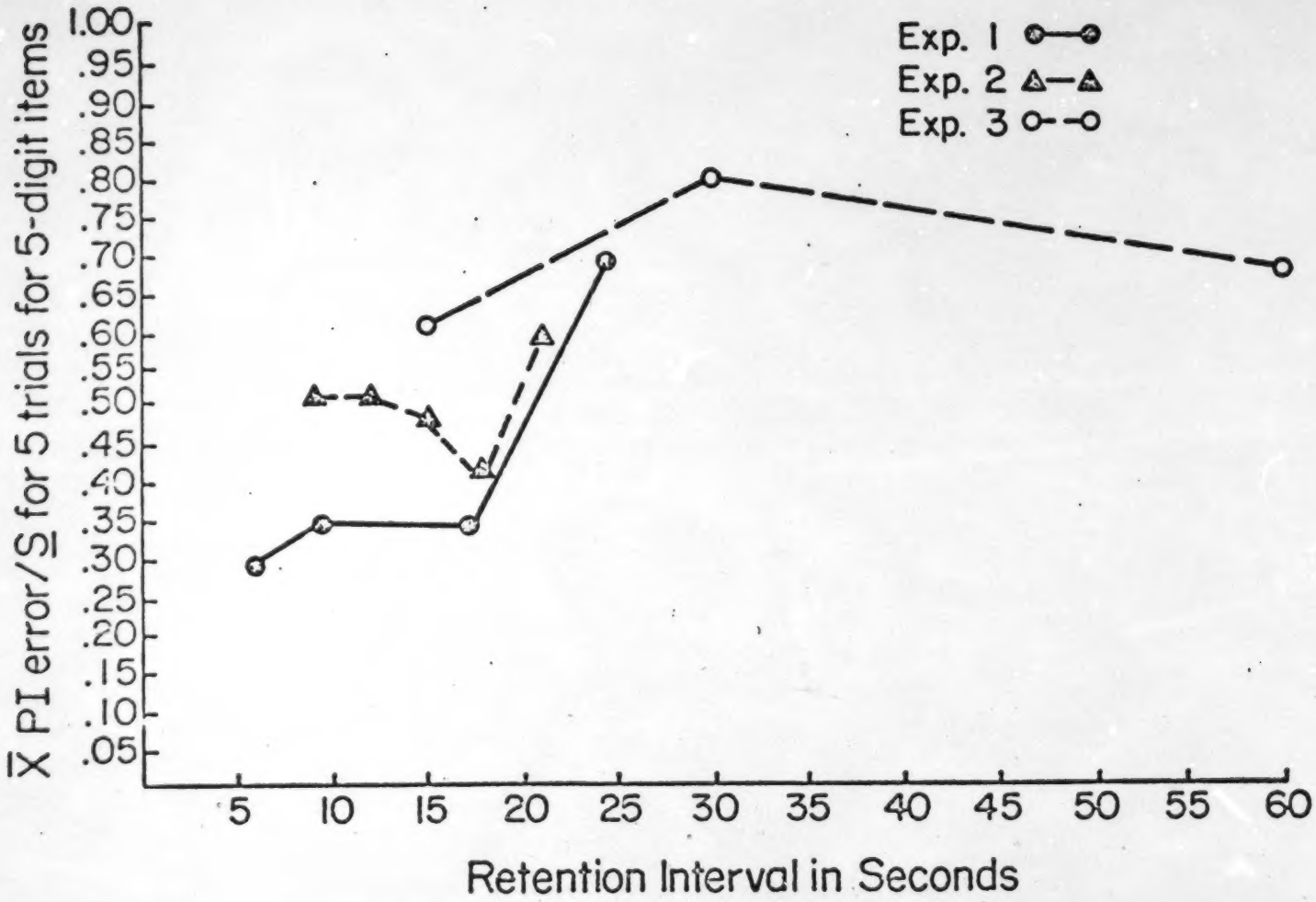

Figure 2. Percent recall of 3- and 5-digit items as a function of the varying retention intervals used in Experiments 1, 2, and 3.

Experiment 3

In Experiment 3, the retention intervals were simply extended up to a maximum of 60 seconds, and 3-digit as well as 5-digit memory items were included. The same trial sheet was used as in Experiment 2 with trials originally designated 9, 12, and 15 seconds changed to 15, 30, and 60 seconds, respectively. (To keep the sessions down to 30-40 minutes, we did not replace the 18- and 21-second trials used in Experiment 2). The two practice trials lasted 30 seconds each, followed by the experimental trials. There were 30 subjects; 15 were given 3-digit memory items, and 15 5-digit items. Retention interval was a within-subjects variable.

Results and Discussion

Mean recall at 15, 30, and 60 seconds, respectively, was 97, 92, and 82% for 3-digit items, and 65, 52, and 51% for 5-digit items (see Figure 2). A 2 x 3 repeated measures ANOVA was completed with memory item and retention interval as the main factors. Memory item size was found to be highly significant, $F(1, 28) = 20.48$, $p < .001$, as was retention interval, $F(2, 56) = 5.66$, $p < .01$. There was no significant item-by-interval interaction, $F(2, 56) = 1.09$.

The error analysis showed that of the 24 errors with 3-digit items (20 items missed), 38% were PI errors and 25% were II errors. Of 225 memory items, only 7 items (3%) were forgotten for reasons other than PI and/or II. For 5-digit items, there were 141 errors, 96 items missed, 30% PI, and 43% II. Of 225 items, 14 (6%) were forgotten for reasons other than PI and/or II (see Table 1).

Experiment 1 produced solid evidence of the importance of modality effects in STM forgetting. With an interpolated task which required processing in a totally isolated modality, only .6% of 3-digit and 4% of 5-digit items were forgotten for reasons other than associative interference.

In Experiment 2, the intervals from 9 to 21 seconds were closely examined and virtually no time loss or attention effects were found. The increase in unaccounted-for errors (from 4% to 9%) may have been due to output interference (since the within-subjects design may have caused subjects to be startled by the recall cue, i.e., they could not anticipate when the pattern-matching would stop). In addition, there might have been a greater amount of remote PI with 25 trials, rather than 12.

In Experiment 3, the retention intervals were extended to 15, 30, and 60 seconds, with only a slight increase in forgetting. These data correspond to results obtained by Reitman (1971) and Shiffrin (1973) which indicated that ST retention is quite good if the retention interval involves processing of modality-isolated information.

Without PI and II errors there seems to be little, if any, memory loss. (Compare Figures 2 and 3 for 5-digit items). In this study, the only apparent memory loss occurred within the first 9 seconds (in Experiment 1) and between 21 and 30 seconds. Between 9 and 21 seconds, there was virtually no memory loss and no increase in PI and II errors. Memory loss was also slight from 30 to 60 seconds, and, again, the error rate did not increase.

The observed increase in PI from 20 to 30 seconds corresponds to

findings reported by Meudell (1977), Warrington and Baddeley (1974), and Yarmey (1974). Since this study was a modality reversal of the Meudell study, this convergence strongly suggests that an increase in PI from 20 to 30 seconds is a reliable phenomenon when interpolated processing is isolated from memory item processing. Our data also suggest an extension of Meudell's hypothesis (following Yntema & Trask, 1963): The discrimination of temporal cues during memory search may be a critical factor in auditor-verbal as well as visual/nonverbal short-term memory. That is, when the time interval reaches a certain length, the subject has difficulty discriminating current items from preceding items on the basis of temporal information.

Results obtained in this study do not support Reitman's (1971) suggestion that the number of decisions made during the interpolated task is critical in ST forgetting. The data also conflict with Yuille and Ternes' (1975) assertion that attention and modality effects are independent. Whereas Yuille and Ternes found only 70% retention of a three-word memory item after 10 seconds of a high-attention visual task, we observed 97% retention of a 3-digit item after 15 seconds; this discrepancy suggests that the Yuille and Ternes task failed to eliminate modality-related interference and, hence, produced spurious attention effects.

The present study supports a multiplicative or interdependent model of memory loss. In such a model, memory loss is viewed as a function of distraction only if the task requires processing within the same modality as the memory item.

In conclusion, our study strongly supports the notion that associative interference and modality effects are vital factors in memory loss. We

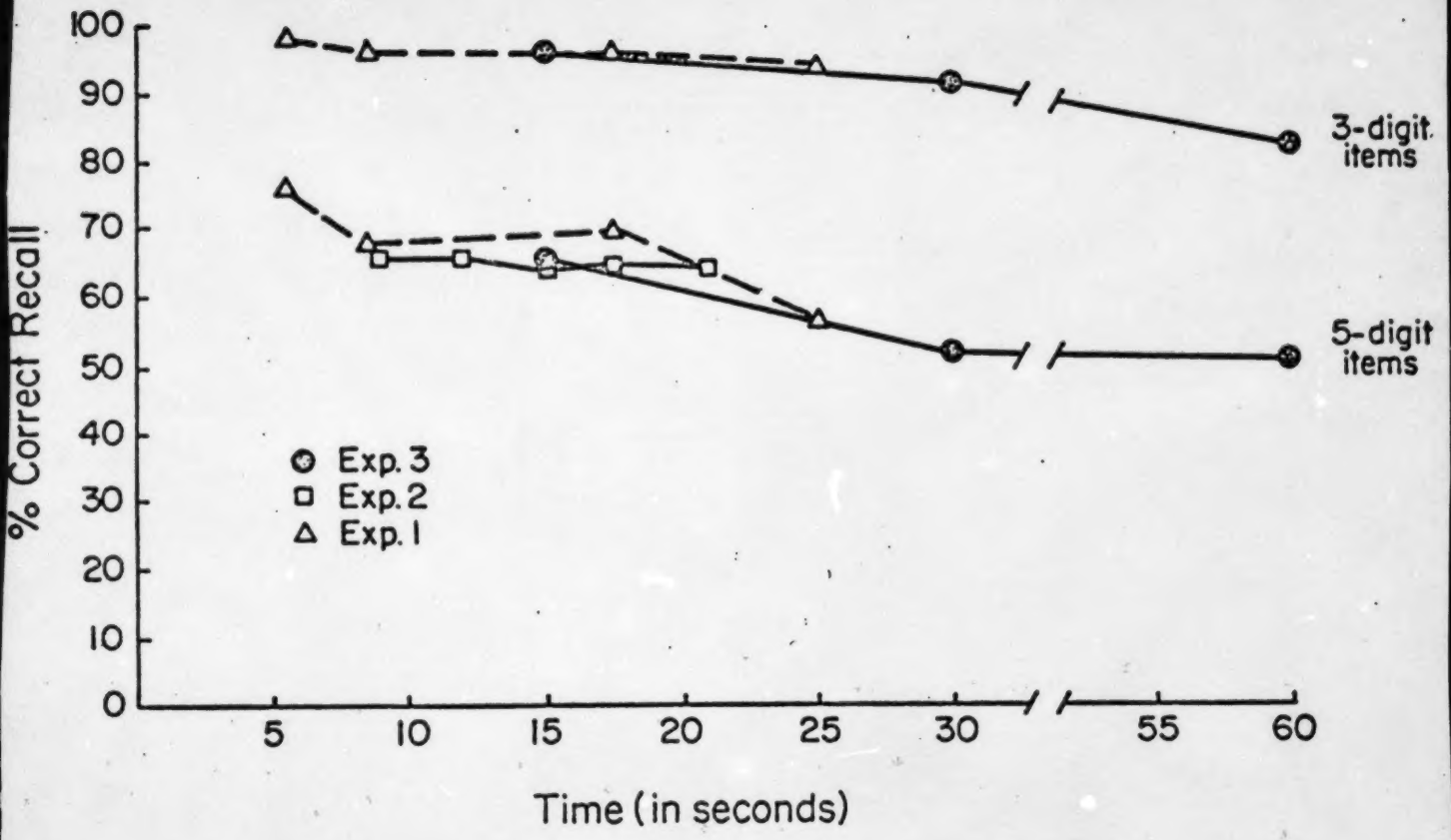

Figure 3. Average number of PI errors per subject for 5-digit items as a function of the varying retention intervals used in Experiments 1, 2, and 3.

found little evidence that either the passage of time, the number of decisions, or the attention demands of interpolated events are critical to ST forgetting.[4] In fact, when RI is eliminated through modality separation, almost all ST forgetting can be attributed to directly measured associative interference effects.

[4]Associative interference does seem to vary with the passage of time, however.

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